ENVIRONMENTAL AFFAIRS

PCS Mining

A subsidiary of the Potash Corporation of Saskatchewan

INVESTIGATION INTO WEATHERING OF THE SURFACE OF POTASH TAILINGS IN SASKATCHEWAN

FINAL REPORT

by R.T. Hart

Environmental Affairs Section

PCS Mining

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EXECUTIVE SUMMARY

Since its initiation in the early 1960's, the Saskatchewan potash industry has produced about 250 Mt of salt waste, which is stored in the 10 tailings piles ranging from 20 to 60 m in height and 50 to 200 ha in area. At abandonment their volume will have been increased by a factor of 4 to 6. The province possesses enough ore to produce an additional 200 tails piles.

Precipitation falling on potash tailings produces large volumes of concentrated brine that if not injected into disposal wells can contaminate local, groundwater supplies. While a mine is in production, serious contamination of groundwater is avoided by active containment measures. Following abandonment, if dissolution of the salt tailings continues at the present rate, containment and disposal practices will have to be continued until the pile has completely dissolved. If, however, the small insoluble component of potash tailings builds up on the surface while the salt is dissolving and forms a crust of low permeability as reported for some piles in the USSR and Germany, the rate of brine production could be significantly reduced. Unfortunately little information is available to indicate that weathering of Saskatchewan tails piles will produce a similar crust.

Laboratory experiments were carried out in order to determine if Saskatchewan tailings had the potential to form an insoluble crust of low permeability. Simulated precipitation equivalent to 1, 3 and 5 years of rainfall (28, 88 and 148 cm) was applied to 7.8 cm dia., columns containing 18, 33 and 55 cm of tailings, respectively. Following application of the above rates, the time for an additional 2 cm of water to drain from the tailings surface was recorded as an estimate of surface permeability. Percent insol content of the leached tailings was then determined.

Percent insol content of potash tailings increased with increasing volumes of leaching water. The top 3 cm of leached potash tailings had average

insoluble contents of 2.2%, 7.4% and 9.5% over those of the untreated tailings. Insoluble content for untreated tailings ranged from 1.4% to 1.6%. Permeability of the leached tailings decreased with increased insoluble content. The leached tailings which received 28 cm, 88 cm and 148 cm H_2O required 41, 155 and 492 secs. respectively, for the 2 cm to drain.

These results are encouraging and will be followed up by field scale investigations.

SOMMAIRE DE L'EXECUTIF

Depuis son implantation en Saskatchewan au début des années 60 l'industrie de la potasse a produit environ 250 millions de tonnes de déchets salins qui sont accumulés dans 10 tas de résidus dont la hauteur varie entre 20 et 60 mètres et qui couvrent une superficie allant de 50 à 200 hectares. Lorsque l'exploitation de la potasse cessera, le coefficient d'augmentation de ce volume sera de 4 à 6. La province possède assez de minerai pour produire 200 tas supplementaires de résidus.

Les précipitations atmosphériques tombant sur les résidus de potasse produisent de grandes quantités de solutions concentrées qui contaminent les réserves locales d'eau souterraine, si on ne se débarrasse pas de ces solutions par injection dans des puits. Lorsqu'une mine est en production, on évite une sérieuse contamination des eaux souterraines en adoptant d'énergiques mesures de retenue. Si la dissolution des résidus salins se poursuit au rythme actuel, il faut, lorsqu'on cesse l'exploitation d'une mine, continuer les travaux de retenue et d'élimination jusqu'à dissolution complète du tas de résidus. Cependant, si les petites parties insolubles qui composent les résidus de potasse s'accumulent pour former à la surface une croûte de basse perméabilité comme cela se produit dans certains tas de résidus en Russie et en Allemagne, dans ce cas la production de solutions salines pourrait etre grandement diminuee. Malheureusement nous avons peu de données qui nous indiqueraient si l'influence des précipitations atmosphériques produirait une croûte similaire sur les tas de résidus en Saskatchewan.

On a fait des expériences de laboratoire pour savoir si les résidus de la Saskatchewan pouvaient former une croûte de produits insolubles de faible perméabilité. Des précipitations simulées équivalentes à une,

trois et cinq années de chutes de pluie (28, 88 et 148 cms) appliquées à des colonnes de 7 cms 8 de diamètre et contenant respectivement 18, 33 et 55 cms de résidus. Après la mise en oeuvre des quantités mentionnées précedemment, les premiers 3 cms des résidus de potasse filtrés avaient des niveaux de produits insolubles de 2.2%, 7.4% et 9.7% plus élèves que les residus non traités. La teneur en produits insolubles des résidus non traités variait de 1.4% à 1.6%. La perméabilité, qui se mesure par le temps requis pour 2 cms d'eau pour être évacuée d'une surface contenant des résidus filtrés, dimunuait avec la quantité de produits insolubles. Il a fallu une durée respective de 44, 155 et 492 secondes a 2 cms d'eau pour sortir des colonnes dans lesquelles les résidus filtrés avaient recu respectivement 28, 88 et 148 cms d'eau.

Ces résultats sont encourageants et on tiendra compte au cours d'autres études qui seront faites sur place.

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1.0 INTRODUCTION

Since the initiation of potash mining in the early 1960's, Saskatchewan has produced 10 tailings piles totalling about 250 Mt of salt waste. These salt tailings which are comprised of NaCl with up to 10% insoluble (insol) material (clays, silts, and sands) are spigotted to the waste management area. Piles range from 20 to 60 m in height and cover 50 to 200 ha each. In addition, an equal area is taken up by brine ponds. Since each mine-refinery complex is expected to remain operational for 65 years, these piles will increase 4 to 6 fold in volume. Considering that Saskatchewan's economically recoverable potash reserves are estimated to range from 9 000 - 14 000 Mt of K_2O (14 - 22 Gt KCl) (Sheldrick and Stier 1978, Energy Mines and Resources 1982), an additional 200 mines and waste management areas containing more than 20 Gt of tailings and covering 1 600 km^2 of agricultural land would be required to exhaust this ore body. This is assuming that waste management practices remain as they are today.

Containment and disposal of processed brine and brine resulting from dissolution of salt tailings by precipitation is the most important environmental concern facing the potash industry. Brine contamination of local groundwater is minimized through maintenance of an extensive system of dikes, and active containment practices such as pumped drains and ditches, and hydrodynamic containment. Brine inventories are kept to an operational minimum by disposing of brine by deep well injection into saline aquifers. After the active life of the potash mine, brine management could continue for 400 to 500 years until the salt tailings have dissolved.

All the abandonment options reviewed by PCS Mining (Hart 1985) which included capping the tailings with soil material, actively dissolving the piles with low grade water and injecting it into deep saline acquifers, and continuing operation of present waste management practices are extremely expensive. However, literature from Germany and USSR report that following

abandonment, the surface of potash tailings undergo changes in response to precipitation which could greatly decrease the production of waste brine from a pile and lessen its impact on the environment. As the salt dissolved, insol content increased resulting in an insol crust of low permeability. In the USSR, Golovin (1976) reported that after 2 to 3 years, a 2 to 8 cm crust formed on level surfaces of potash tails piles in the Soligorski region. Surface differentiation was even more pronounced in potassium waste piles located in Germany where a 50 cm salt-free layer of insoluble material developed after 15 years (Heinze and Fiedler 1979).

The development of an insoluble crust of low permeability could result in a reduction in the rate of brine generation. Precipitation contained on the surface of the crust or within the insol layer would increase evaporative loss and decrease the amount of water available for pile dissolution. If brine production from an abandoned pile decreased sufficiently, impact on local ground water resources might be reduced to an acceptable level without further mitigation. This would result in a decrease in costs of long term waste management.

Unfortunately it is not known at what rate or even if a similar insoluble layer could develop on Saskatchewan potash tailings piles following abandonment, and what effect it would have on overall rate of pile dissolution, and groundwater impact. The Saskatchewan situation differs from Europe in that the insoluble content of Saskatchewan ore and tailings is generally lower and the climate more arid, with less leaching water available from precipitation. In addition, Saskatchewan's tailings are relatively young and frequently disturbed by spigotting. In a few cases where accummulation of insols has been observed on PCS Mining's tailings, background information on initial surface insol content and texture, and time frame does not exist.

It is the objective of this investigation to determine if, under

laboratory conditions, an insol layer of low permeability would develop on the surface of Saskatchewan potash tailings, in response to the leaching which would occur after 1, 3 and 5 years of precipitation.

2.0 MATERIALS AND METHODS

In order to simulate weathering on potash tailings, water equivalent to 1, 3 and 5 years of rainfall was applied to triplicate sets of 7.8 cm ID PVC columns containing 18, 33 and 55 cm of tailings. Tailings resembling coarse textured sand were loaded into the columns and lightly compacted as the columns were filled. Fresh tailings material was collected from the surface of the tailings pile at PCS Mining, Cory Division. Prior to loading into the transparent columns the tailings were broken into a granular free flowing form.

A particle size analysis was not performed. A previous study of PCS Mining (Johnson 1984) indicated that insols of silt size were most prevalent in samples collected within the refinery at PCS Mining, Cory Division. Fine sand and clay sized material comprised about 1% and 30% of the insols, respectively. This distribution is not likely representative of the insoluble material occurring in samples used in this investigation which were taken from the top of the tails pile. It is likely that the insolubles in these samples contain a greater proportion of silts and sands since the finer material would be carried to the toe of the tailings pile in the spigotting discharge.

Clear PVC columns were used to observe vertical differentiation and to ensure that tailings dissolution was uniform and that dissolution channels were not formed. To insure adequate column drainage, the columns were placed on a coarse gauge screen. The brine draining from the screen was discarded. Following application of 28 cm (1 337 mL), 88 cm (4 203 mL) and 148 cm (7 068 mL) of tap water at room temperature (19°C) onto the surface of the 18, 33 and 55 cm tails columns respectively, permeability of the surface was measured as well as changes in insoluble content. Two of the three tailings columns in

each set received the above application of water in the form of simulated precipitation delivered by a peristaltic pump (Masterflex) and #14 gauge rubber tubing of 2 mm ID, supplied by the Cole-Parmer Instrument Co. (Photo 1). The water was applied in 1 L units and the time to apply each unit was recorded. The application rate was sufficient to produce saturated flow through the tailings surface. Care was taken to ensure that surface puddling was minimized and that the dissolution of salt tailings was uniform. The rapidly eroding nature of the tailings surface necessitated manual, as opposed to automated application of leaching water.

In order to assess for future experiments if this time consuming method of applying leaching water was necessary, water was applied to the third column of each set not in drops but rapidly in quantities sufficient to fill the columns. Water was continually added to the columns until 1 L had been applied. The tails surface was then allowed to drain before an additional 1 L unit was applied. The time for each 1 L unit to drain was recorded. Application was by a simple syphon tube (7 mm ID) extending from a 1 L beaker.

Thirty minutes following the application of the leaching water, the relative permeability of the remaining tailings was estimated by measuring the time for 2 cm of column water (96 mL) to drain from the surface of the tails column. This water was applied rapidly using 2 pump heads delivering a total of 250 mL/min. This additional 2 cm of water increased the total amount of leaching water to 30 cm, 90 cm and 150 cm. Due to a fairly constant leaching volume to salt dissolution ratio, the total height of the remaining tailings following leaching varied little, ranging from 8 to 9 cm for all treatments.

Insoluble levels expressed as percent weight were determined using an X-ray florescence spectrometer (Phillips 1400). Tailings samples were taken prior to loading each column (base line tailings), and from the tailings remaining in the column following leaching and permeability procedures. About

80 cm^3 of baseline tailings and the top 3 cm (140 cm^3) of the leached tailings were dried to 0.1% moisture content using a microwave oven, then pulverized, and mixed. A 14 cm^3 sample was removed for insol analysis by X-ray spectrometry. To determine if insol accumulation occurred preferentially on the surface of the tails, insol values were also obtained for the bottom portion of the leached tailings. This portion was about 5 to 6 cms in height.

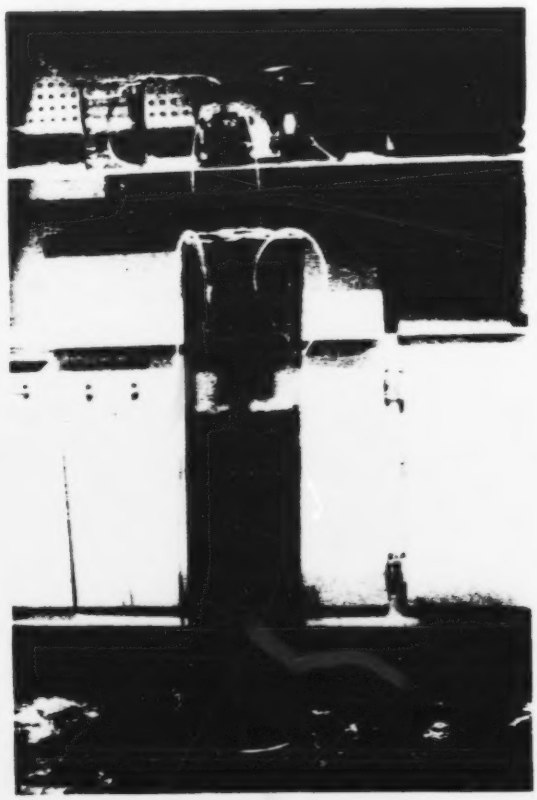

Photo 1. Experimental set up with columns 1 and 2 containing 55 cm of potash tailings resting on a large gauge screen to insure adequate column drainage. Peristaltic pump in background with leaching water.

3.0 RESULTS

The results clearly indicate that insoluble content of potash tailings increases with the volume of leaching water applied (Table 1). This trend is

apparent for columns 1 and 2 which received leaching water in the form of simulated precipitation, as well as in the case of column 3 where leaching water was applied rapidly and in large volumes. Increase in insolubles was found to be greater for columns receiving simulated precipitation.

Build up of insols was greatest for all columns in the top 3 cm. The rate of increase in insol accumulation relative to volume of leaching water was greatest for columns receiving 90 cm of column water (Table 1). The rate of increase in insols for the top 3 cms between the 90 and 150 cm treatment was half that occurring between the 30 and the 90 cm treatment. Insol content on average did not increase for the 90 cm and 150 cm treatments for the lower portion of the leached tailings.

The insolubles which accumulated on all leached surfaces appear to be predominantly brown, fine grained material (Photo 2,3). In addition, some small quantities of fine to medium sized sand was evident on all leached surfaces. These sands ranged from a very light color to black. A grain size analysis was not performed on these samples.

Table 1. Percent insolubles in columns of potash tailings before and after application of 30, 90 and 150 cm of leaching water.

		Leaching H_2O Applied (cm)		
		30	90	150
Top 3 cm of Leached Tailings				
Columns	1	3.77	8.71	11.11
	2	3.55	8.84	10.56
	3	2.81	5.55	10.30
Bottom 5 to 6 cm of Leached Tailings				
Columns	1	2.09	4.83	5.19
	2	2.16	4.95	4.57
	3	2.17	3.55	3.87
Baseline Tailings				
Columns	1	1.42	1.45	1.37
	2	1.55	1.39	1.36
	3	1.49	1.34	1.43

Photo 2. Leached tailings following application of 150 cm H_2O compared to untreated tailings on the far right. The two columns on the left received 148 cm of simulated precipitation. The tailings immediately to the right of the marker received the same volume of leaching water but more rapidly. All three received an additional 2 cm of H_2O as a permeability test. The tailings on the far right was untreated.

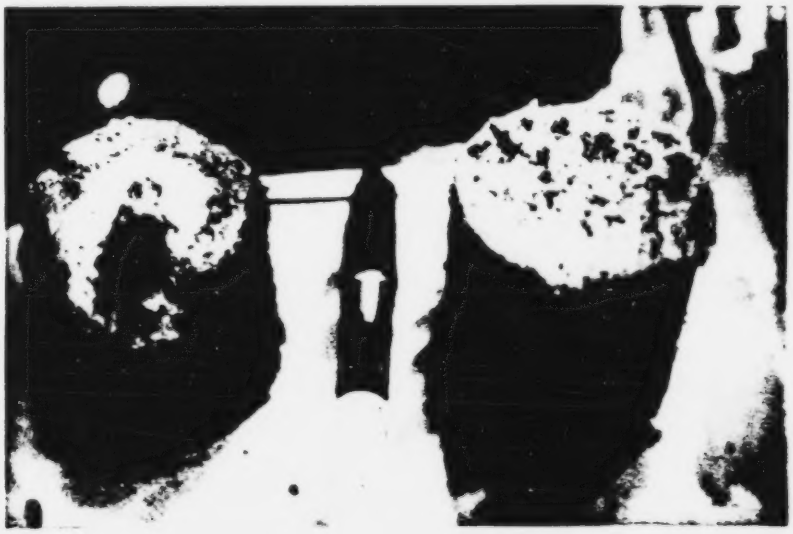

Photo 3. Insol build up is obvious on the tailings left of the marker which received 150 cm of leaching water. The surface of the untreated tailings to the right is characterized by a granular texture with no tailings differentiation.

The increase in insoluble content for all leached tailings surfaces was accompanied by an increase in the time required for 2 cm of column water to drain from the tailings surface (Table 2). This decrease in permeability with increasing insol content occurred for tailings columns receiving leaching water as simulated precipitation, as well as for those columns which received the leaching water more rapidly (columns #3). The latter columns did however drain slower inspite of lower insol levels relative to column 1 and 2. Surface drainage times for columns 1 and 2 were very similar, except for one of the columns which received a 148 cm treatment. Surface solution channels developed in this column, rapidly draining the tailings surface.

In addition to the above estimate of permeability, the time required to apply leaching water to all columns was also recorded for this purpose. Total time elapsed for application of 28 cm (1 337 mL), 88 cm (4 203 mL) and 148 cm (7 068 mL) of leaching water was on average 37, 157 and 405 minutes for the volumes receiving simulated precipitation, and 13, 46 and 165 minutes for the columns (column #3) in which leaching water was applied rapidly and in large volume. The faster drainage for columns receiving the latter application was expected due to the head build up above the tails surface as well as to a smaller insol accumulation.

Table 2. Time for 2 cm of water to drain from the surface of leached columns of potash tailings.

		Leaching H_2O Applied (cm)		
		28	88	148
Time to Drain (min:secs)				
Columns**	1	0:43	2.53	8:12
	2	0:39	2:16	1:19*
	3	1:04	3:11	11:08

* Rapid drainage due to development of solution channels.
** Columns 8 to 9 cm in length.

4.0 DISCUSSION

The application of leaching water in volumes equivalent to 1, 3 and 5 years rainfall to columns of potash tailings resulted in surface increases in the insoluble content of potash tailings. Accompanying this increase in insols was a decrease in surface permeability.

These results indicate that an increase in insoluble content and a decrease in permeability of salt tailings could occur on Saskatchewan tails piles. It is likely that the insol crust observed on some portions of the tailings pile at PCS Mining's Cory Division is due to weathering of the pile's surface. The decrease in permeability with increasing insol content was reported by Johnson (1984) in his characterization of potash wastes at Cory Division. He found a steady increase in permeability from 10^{-1} to 10^{-7} cm/s for tailings with 0% to 40% insoluble content, respectively. The estimates of permeability determined for this investigation are similar to permeabilities reported by Johnson for insol contents to 10%.

Due to several factors which were not considered in this investigation, the possible extent and time frame of changes in insol content and permeability on the surface of an actual potash tails pile remain unknown. This investigation was performed on tailings material less dense than the extremely hard and compact material characteristic of an actual tailings pile. The loose granular nature of the salt tailings used in this experiment may have allowed more downward insol movement and less surface accumulation of insols than would normally occur. In addition the rate of application of leaching water was much greater under experimental conditions than would be expected from natural precipitation. This resulted in saturated flow occuring much of the time throughout the column, which would also likely be conducive to vertical insol movement.

While the denser and less permeable tailings characteristic of an intact pile, and lower frequency of saturated flow conditions might accelerate insol accumulation in the field, their effect could be more than offset by insol loss due to surface erosion under field conditions. Erosional losses of insols did not occur at the surface of the tailings columns but are likely on a tails pile where the surface inclination ranges from 1° to more than 35°. As insol content increases and permeabilities decrease, erosion of the fine silt and clays characteristic of potash insols can be expected.

If the net effect of weathering is an increase in insols on the tailings pile's surface, then a gradual desalinization of the crust might occur as noted in Germany (Heinze and Fiedler 1979). The extent of this desalinization and its influence on the concentration of brine discharged from run-off from the tails pile surface would depend on the relative importance of downward leaching by precipitation versus upward migration of salts in the crust. The latter is caused by moisture evaporation from the surface and upward capillary movement of brine into the insol crust from the raw tailings below. Due to the arid environment of the prairies it is expected that upward salt movement would be significant.

In order to evaluate the influence of these factors on tails piles weathering and brine discharge, field investigations are required. Although due to time constraints these investigations must be carried out over a compressed period of time, undisturbed sites undergoing natural weathering must be characterized and monitored carefully over the long term, to insure that the experimental findings accurately reflect actual weathering of potash tailings in an arid prairie environment.

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